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None

(58) Field of search
H1Q

(54) A 16-port wideband butler matrix

(57) A 16 × 16-port wideband Butler matrix comprises cascaded stages A, B, C, D of four-port power dividers each divider having a fixed phase difference of either 90° or 180° between its output ports, the first and last stages each having eight such dividers. One output from each of four of the first stage dividers includes a fixed wideband 22.5° phase shifter. A common source signal fed commutated to the 16 input ports will produce 16 different output combinations of 16 signals each with a 22.5° phase increment between the 16 outputs.

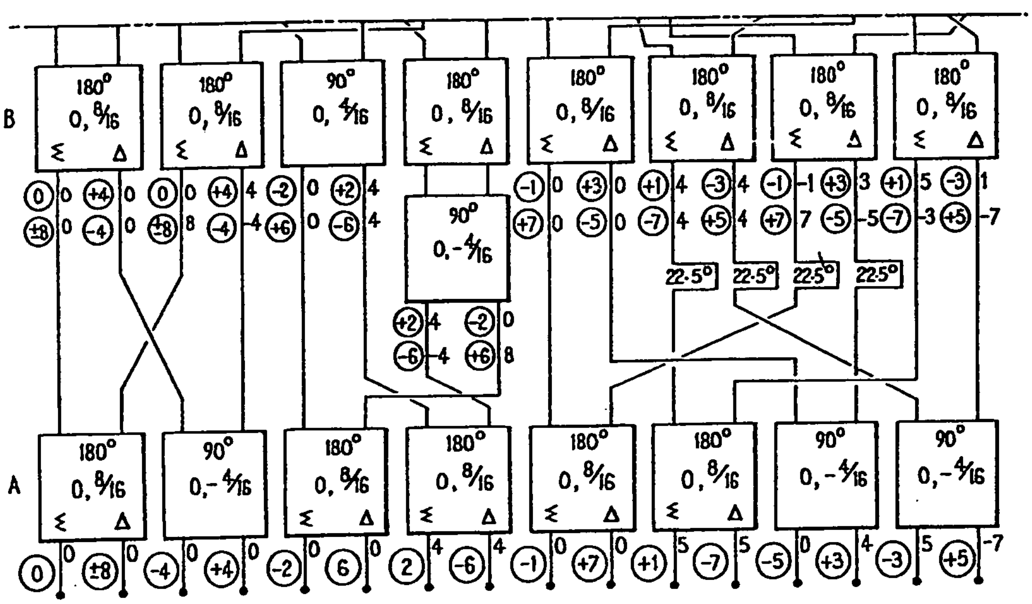

FIG.1c

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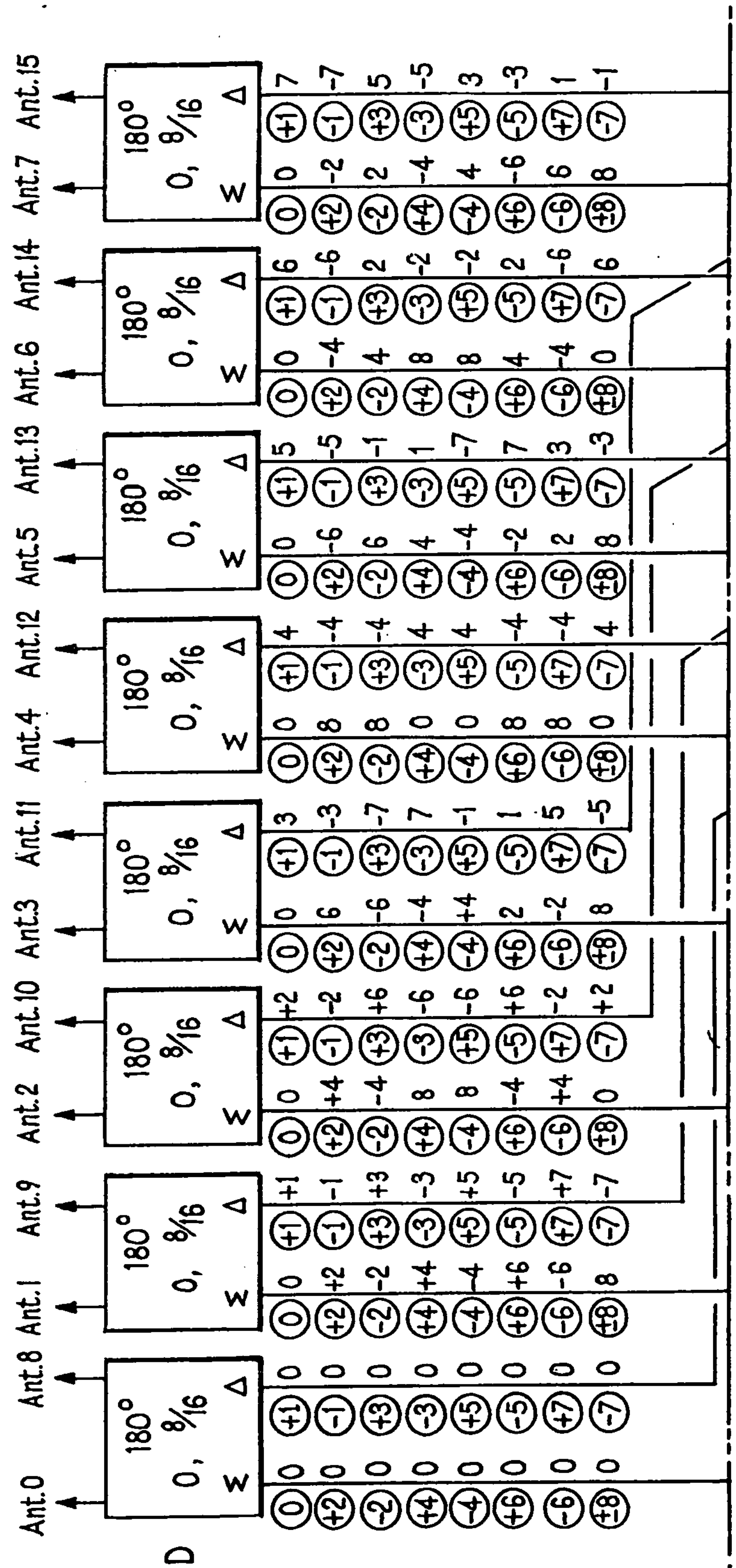
The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.


Ant.0
Ant.8
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Ant.4
Ant.12
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Ant.6
Ant.14
Ant.7
Ant.15
180°
0, 8/16
W
Δ
D

FIG.1a

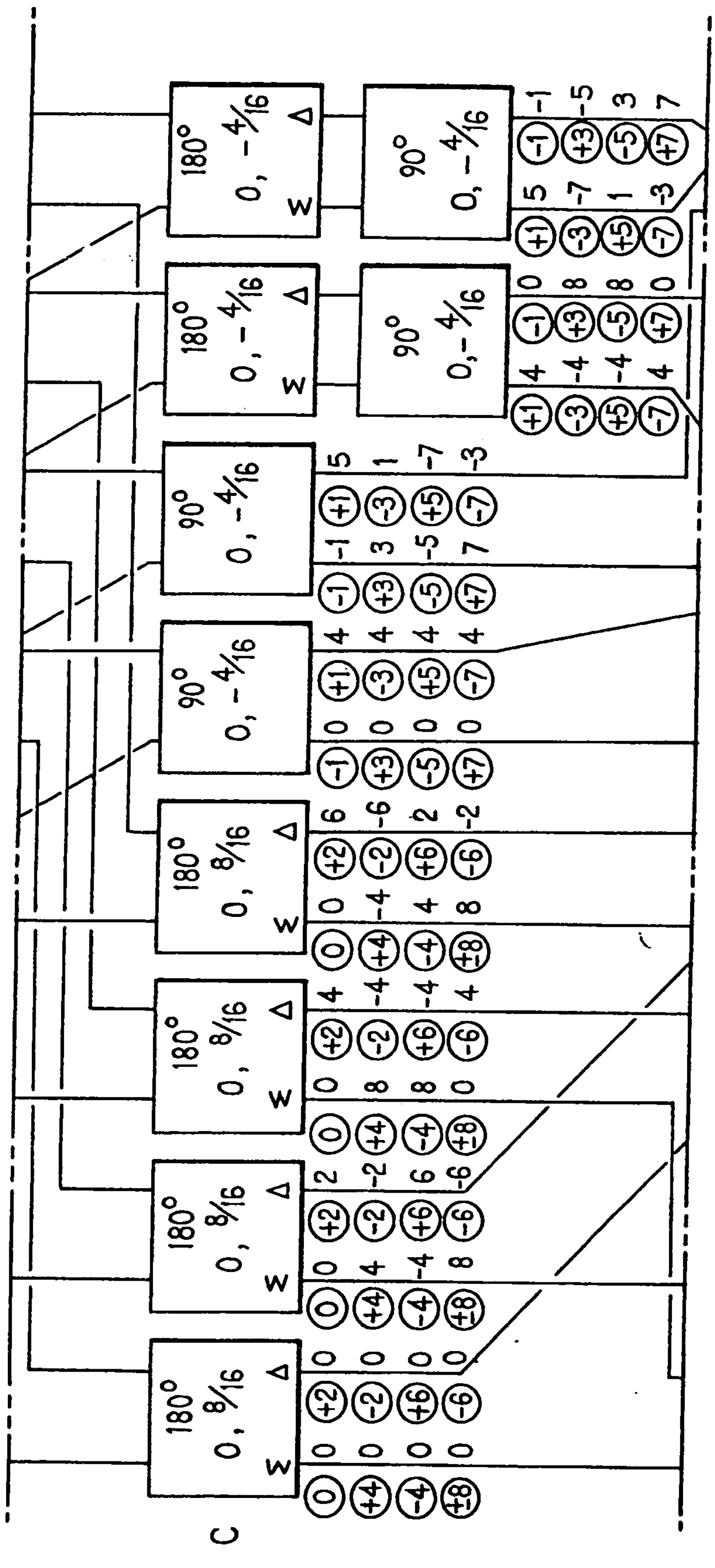

FIG.1b

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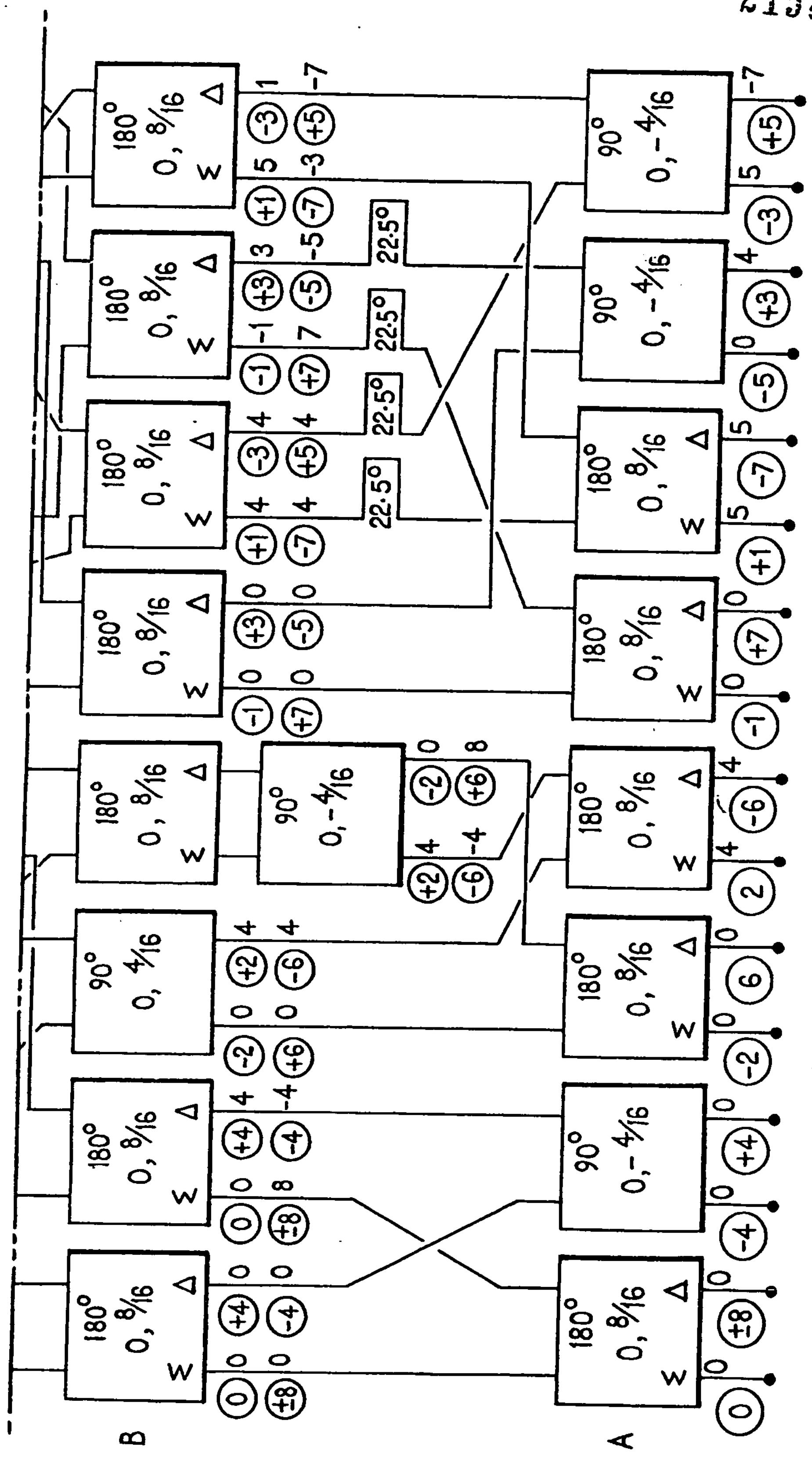

FIG.1c

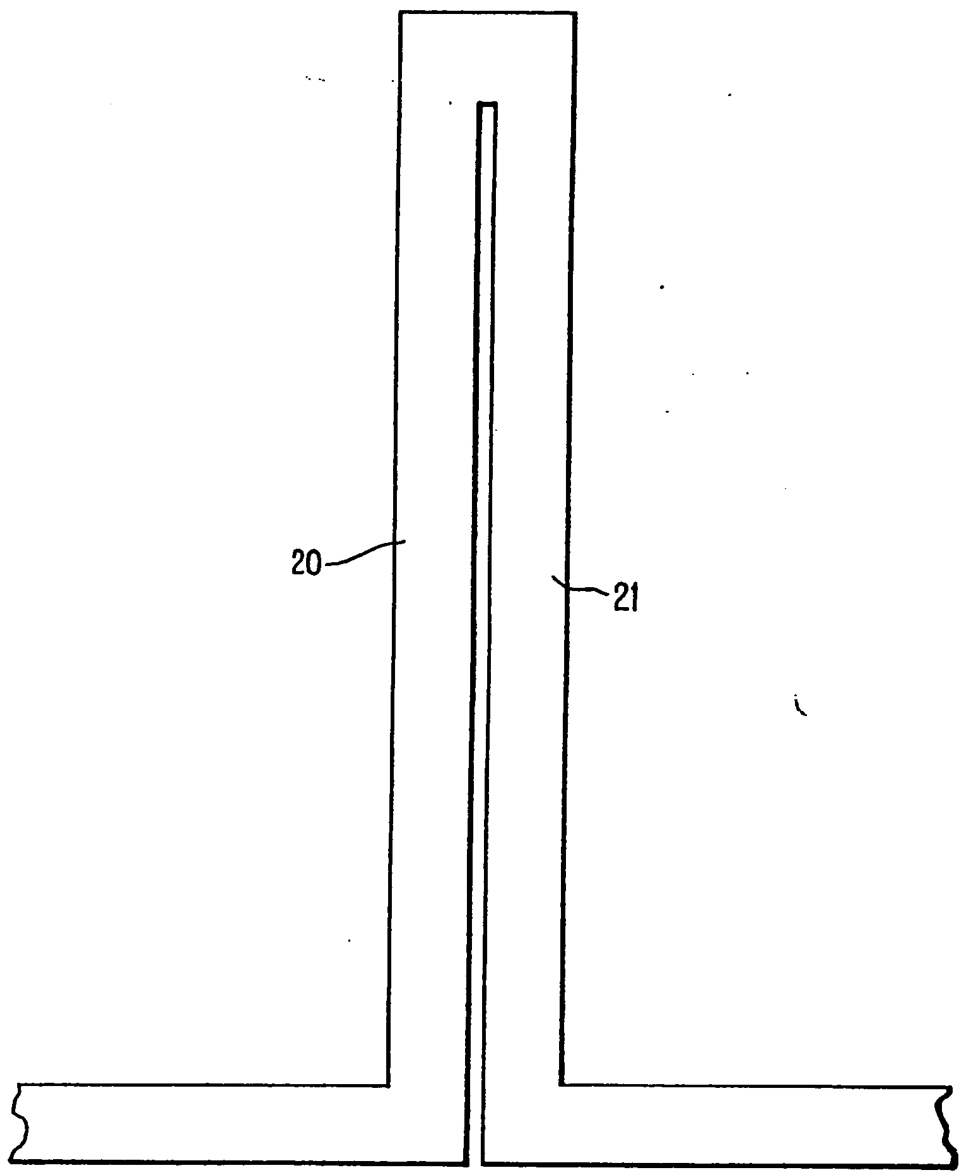

FIG.2

SPECIFICATION

A 16-port wideband butler matrix

This invention relates to a 16-port wideband Butler matrix having low loss, and is particularly applicable as an r.f. feed network for antenna arrays.

In U.S. patent 3,255,450, inventor Jesse L Butler, there is disclosed an antenna array feed network for directional beam steering through selective phasing of signals from a plurality of antennas, said signals deriving from a common source. The network is a so-called matrix comprising a series of cascaded stages each stage having a number of four-port power dividers. The dividers have the property of coupling a signal from either of first and second ports to the third and fourth ports with a fixed phase difference between the signals at the third and fourth ports and with equal amplitudes at the third and fourth ports. The matrix disclosed in patent 3,255,450 refers to the use of dividers in which the fixed phase difference between the output signals at the third and fourth ports is 90°. However, four-port power dividers can also be constructed in which the equal amplitude outputs have fixed phase differences of 180°.

The standard Butler matrix is suitable for 4-input × 4-output circuits, or 8 × 8 circuits, whereby switching of a single source signal to different matrix inputs results in different directional beams from the antenna elements of a linear antenna array connected to the matrix outputs. Thus with eight antennas of a linear array connected to an 8 × 8 matrix a set of eight different beams can be produced with signals from the single source. In the case of a circular array the constant gradient phase sequences do not directly, on their own, produce beams but omnidirectional radiations of distinctive phase gradient in azimuth. These sequences are called phase modes. For many practical purposes it is desirable to provide at least a 16 element circular array, with element excitation at multiples of 22.5°. Whilst wideband 4 × 4 or 8 × 8 Butler matrices with low loss can be produced, expanding the matrix to a 16 × 16 configuration requires assymetrical splitting of the network. In Proceedings of 2nd International Conference on Antennas and Propagation, 1981, Rahim, T., Guy, J.R.F. and Davies, D.E.N in "A wideband UHF Circular Array" propose a 16 × 16 port design whereby certain signals are attenuated prior to being combined in the matrix. The penalty for this is a theoretical minimum insertion loss of 2.3 dB if amplitude equality is to be maintained. For certain applications, however, even this low level of insertion loss is unacceptable, the requirement being for a theoretical lossless distribution of signals. An example of this is to be found in an electronic TACAN beacon, in which a non-rotating circular antenna array requires the use of 16 separately excited elements to form the required pattern.

According to the present invention there is provided a 16 × 16-port wideband Butler matrix comprising cascaded stages of four-port power dividers each divider having a fixed phase difference of either 90° or 180° between the third and fourth port equal amplitude outputs, the first or input stage having eight dividers, one output from each of four dividers in the first stage including in its connection to an input of a divider in the next stage a fixed 22.5° wideband substantially lossless phase shift means.

An embodiment of the invention is described with reference to the accompanying drawings in which

Figure 1 is a schematic representation of a 16-16 wideband Butler matrix, and

Figure 2 illustrates a 22.5° phase shifter.

In Figure 1 there are shown four main stages A-D each of eight fixed 90° or 180° wideband four port power dividers. Various inputs of the dividers in the first stage A are connected to a common signal source via phase shifters (not shown). Likewise the sixteen outputs of the dividers in the last stage D are connected to 16 antennas (not shown). Generally the outputs of stages A, B & C are connected to inputs of stages B, C & D respectively. However, there are additional intermediate dividers Aa and Bb between stages A & B and between stages C & D. Finally, four of the connections between stage A and stage B include fixed 22.5° wideband substantially lossless phase shifters. Thus by selecting appropriate sequences of connection between 90° and 180° dividers of succeeding stages, with or without an additional 22.5° phase shift, it is possible to provide 16 different combinations (modes) of outputs at the 16 antennas for each of the 16 different inputs, each mode consisting of 16 different phases of the common input signal with equal multiples of 22.5° phase difference between the 16 outputs.

As shown in Figure 1, each mode is shown circled, thus (0), (+1), (−2) etc and at each stage the phase relevant to a fixed reference for each mode is shown at the input to each divider, the phase being given as + or − multiples of 1/16 of revolution, i.e. 22.5°. Thus at each input there appears a legend such as (+3) −5, meaning that at that input for mode (+3) the relevant phase if −5/16, i.e. −112.5° from the fixed reference mode notation is (0) for a fixed reference, or central, mode with (+1), (+2) ... (+8) on one side of the reference and (−1), (−2) ... (−8) on the other side, (+8) and (−8) being the same.

The 90° and 180° power dividers are conventional wideband hybrids and are substantially lossless devices. The 22.5° phase shifters are conveniently realised as close coupled sections 20, 21, Figure 2 of a continuous transmission line which have a d.c. continuity and an effectively distributed capacitance between the two sections. Such a structure is known as a Schiffman phase shifter.

When the matrix as shown in Figure 1 is connected to a circular array of 16 antennas, and a common signal source is connected to the input ports of the matrix through appropriate phase shifters, a Tacan pattern is generated in the far field suitable for providing navigational guidance in the same way as does the pattern produced by the current mechanically rotating device.

CLAIMS

1. A 16 × 16-port wideband Butler matrix comprising cascaded stages of four-port power dividers

each divider having a fixed phase difference of either 90° or 180° between the third and fourth port equal amplitude outputs, the first or input stage having eight dividers, one output from each of four dividers in the first stage including in its connection to an input of a divider in the next stage a fixed 22.5° wideband substantially lossless phase shift means.

2. A matrix according to claim 1 wherein the fixed 22.5° phase shift means comprise two close-coupled sections of continuous transmission line with a d.c. continuity and an effectively distributed capacitance between the two sections.

3. A 16 × 16-port wideband Butler matrix substantially as described with reference to the accompanying drawings.

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